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Erection of the Leas Highway Bridge near St. Joseph, Ill.

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ERECTION

OF THE

LEAS HIGHWAY BRIDGE

NEAR

ST. JOSEPH, ILL.

BY

WAYNE EDISON BURKHALTER

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1903

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WAYNE EDISON BURKHALTER

ENTITLED ERECTION OF THE LEES HIGHWAY BRIDGE NEAR ST. JOSEPH, ILLINOIS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering.

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ERECTION OF THE LEAS HIGHWAY BRIDGE

No detailed account of the erection of a highway bridge being available in any of the common texts on bridges or in any of the engineering journals or magazines, an attempt will be made to describe the method used in the erection of a 100-foot span near St. Joseph, Illinois, and then a brief comparison will be made with other methods which have come to the writer's notice. The discussion will be limited mainly to the erection of the superstructure and of the falsework, but as the erection of the new structure involved the removal of the old bridge, the latter will be somewhat briefly considered.

The bridge referred to is a pin-connected Pratt truss of the dimensions given in Fig. 1, page 2 . It is set upon masonry abutments, and may fairly be taken as a typical country highway bridge. The old bridge consisted of a 90-foot pony Howe truss span in the center and a 15-foot span at each end. The spans rested upon cast-iron piles. The old bridge is shown by the photograph on the next page, as is also the configuration of the ground at the east end of the bridge.

The floor at the ends of the old bridge was torn up to build the abutments, but it was replaced and traffic resumed awaiting the arrival of the material for the new span.

The material for the new bridge, when delivered at the site, was distributed as shown in Fig. 3, page 4.

Removal of the Old Bridge

The first step in removing the old bridge was to take off the

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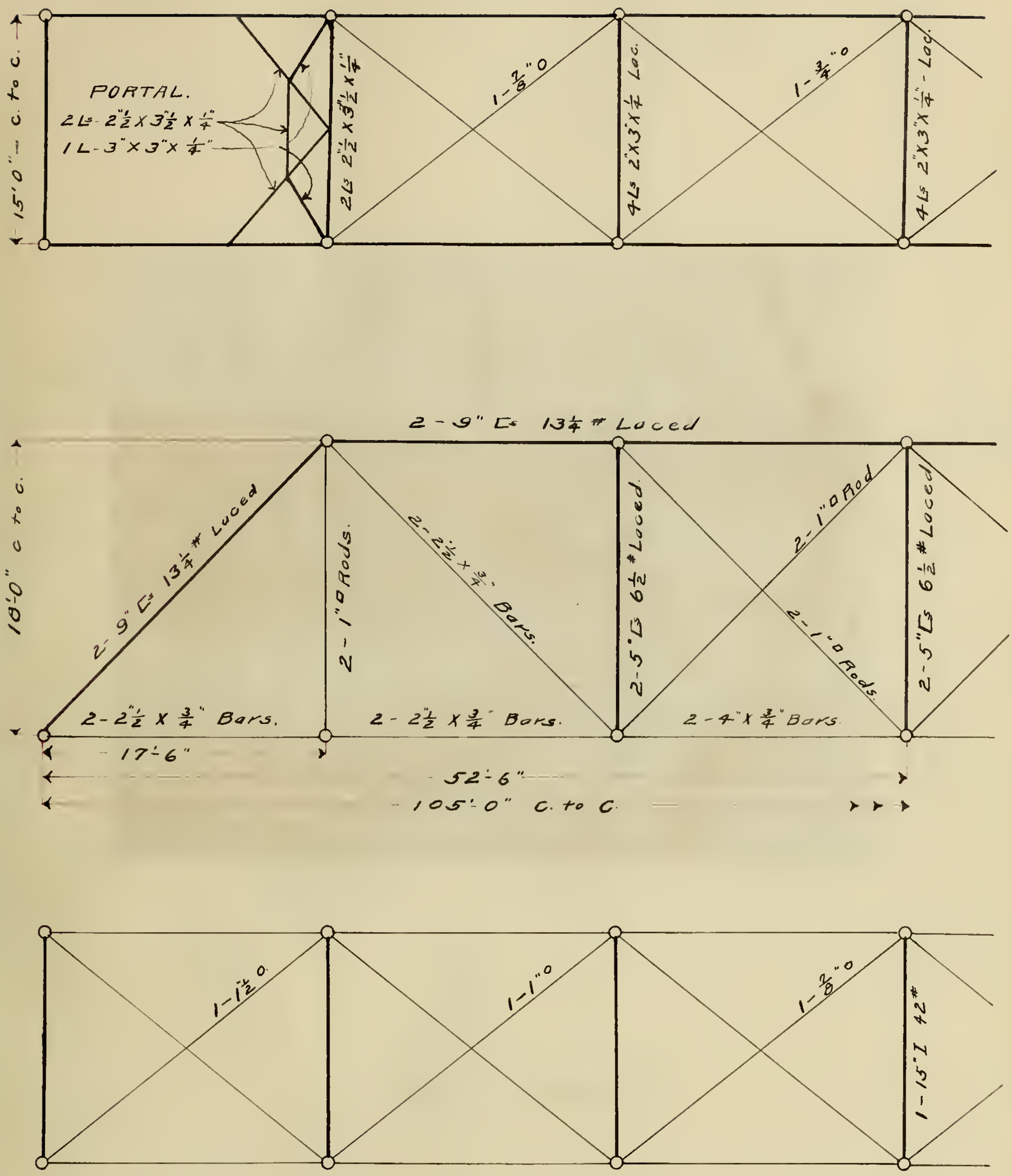

FIG. I.

DIMENSIONS OF NEW BRIDGE.

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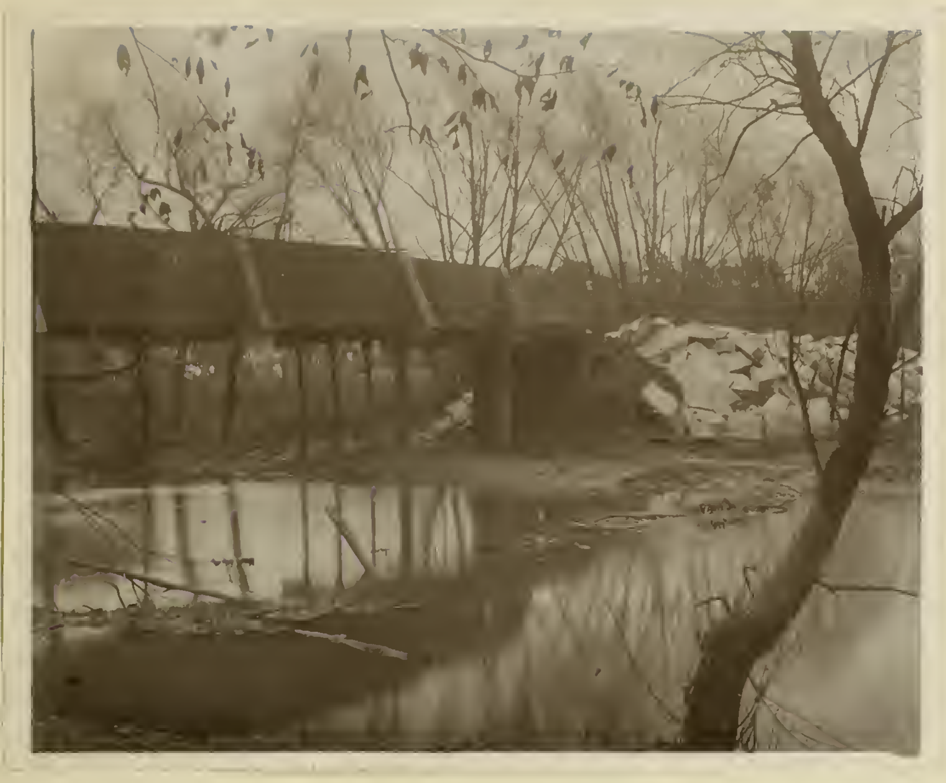

Fig. 2.

OLD BRIDGE.

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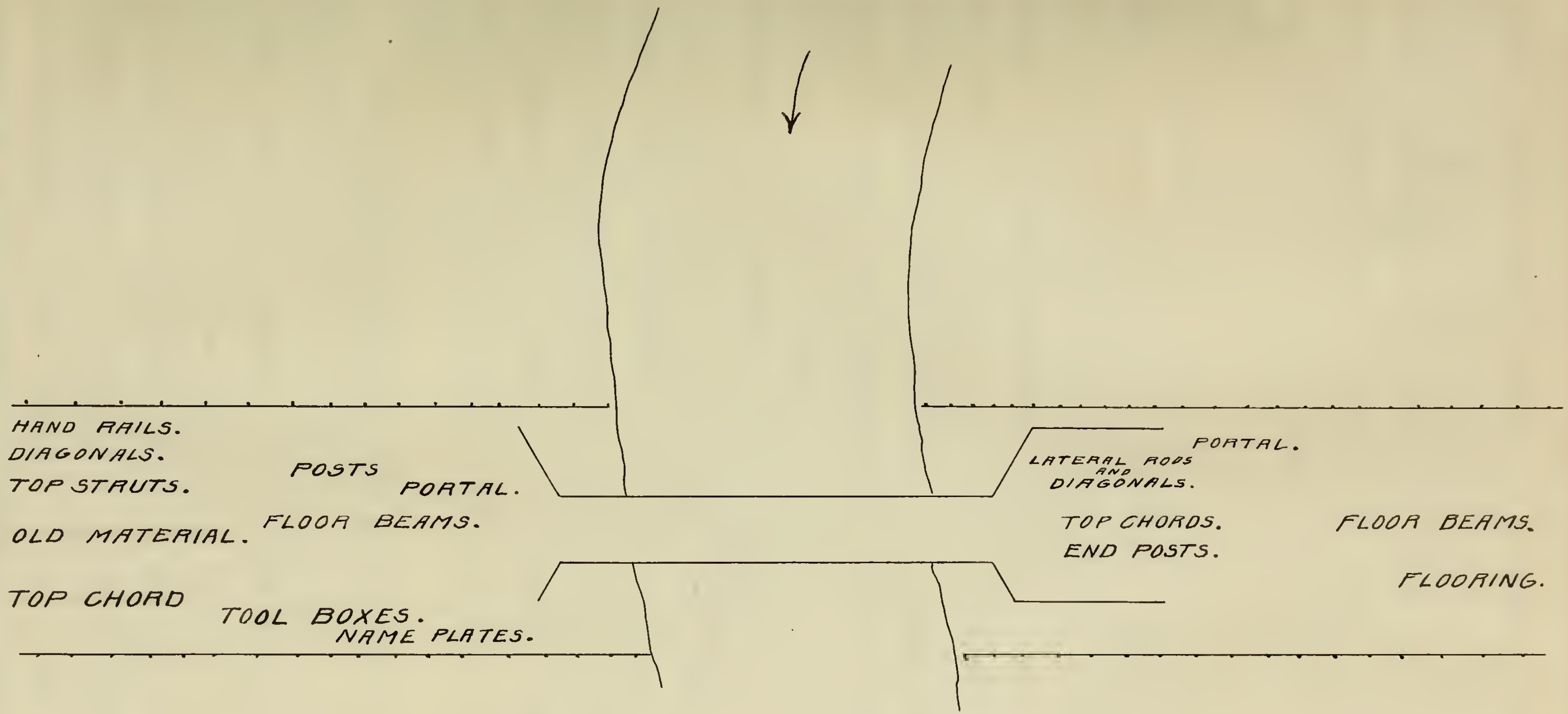

FIG. 3.

SHOWING DISTRIBUTION OF MATERIAL FOR NEW BRIDGE WHEN DELIVERED AT SITE.

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boxing from the Howe trusses and to remove the floor, placing the lumber at the east end near the bridge. Piling was procured from a neighboring farmer and placed (in bents of two) at points corresponding approximately to the panel points of the new bridge. The cast-iron pipes of the old bridge were used as part of the falsework.

The piles were braced with pieces of old flooring bolted diagonally, one on each side of the bent. The cap of the bent consisted of two old flooring boards bolted one on each side of the piles. The top of the cap was three inches below the bottom of the floor beam of the old bridge. Two lines of old wooden stringers, one under each truss, were placed flat side down upon the caps of the pile bents and under the floor beams of the old bridge. Then a double row of old wooden stringers was placed, flat side down, upon the floor beams just inside of each truss, and also a single row was placed midway between the trusses. The tension members of the Howe trusses were now loosened, care being taken to keep all of the rods loose so that too much tension could not be taken by one rod and thus prohibit its easy removal. Loosening these rods allowed the weight of the floor beams and lower chord to come upon the falsework.

An A-derrick was then constructed from old flooring boards substantially as shown in Fig. 4, page 6. This derrick was moved by hand, three men carrying it without difficulty. It was first set up at the center of the panel L_1L_2, Fig. 5, and the block fastened to a chain about the upper chord of the old bridge. The end post was then stayed by an inch piece as shown in Fig. 5. All hands, seven in number, hauled away on the fall line while the foreman with a small pinch bar loosened the joint U_1. After some difficulty at

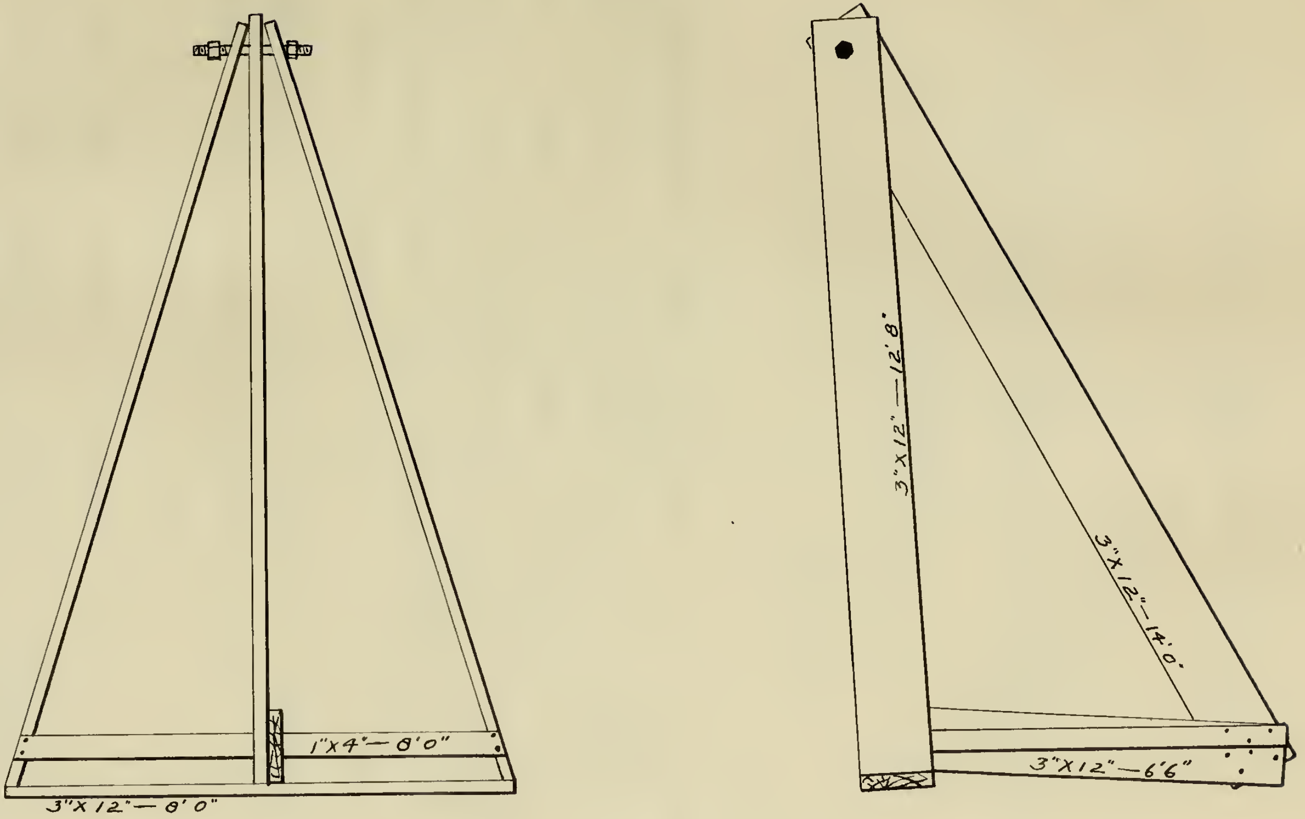

FIG. 4.

DERRICK USED IN TAKING DOWN THE OLD BRIDGE.

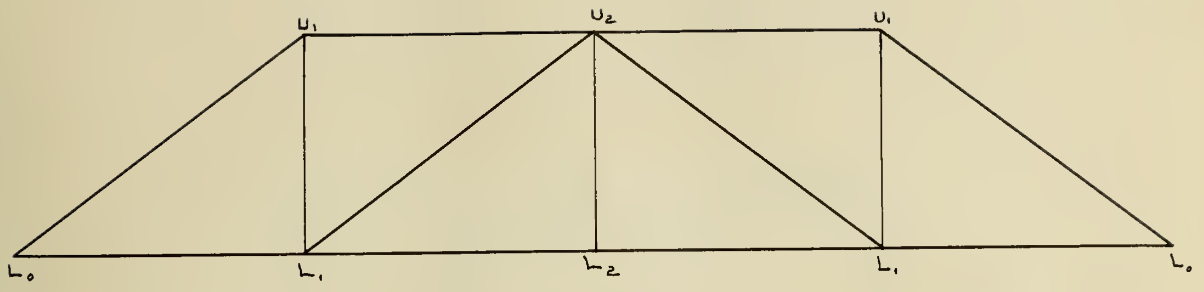

FIG. 5.

the joint U_1, the portion of the top chord U_1U_2 was raised from its place and then lowered to the floor. Although a resolution of forces would show no stress in U_1U_2 after the member U_1L_1 was removed, still by an arch action it carried nearly all of its former stress, and when it was removed the point L_1 deflected about three inches, owing to the vertical component of the additional thrust in U_2L_1. This additional thrust was not great enough to cause serious damage to the falsework. The end post was next laid upon the falsework, two men easily removing it by hand. Then the corresponding members on the other end of this truss were removed in the same manner, as also the two remaining diagonals. After the other truss had been dismembered, the pieces were moved to the end of the bridge by the use of a dolly and placed out of the way. (The dolly is fully shown in Fig. 6, page 8) The derrick was then taken to pieces. Nothing remained above the gangways at this time to interfere with the

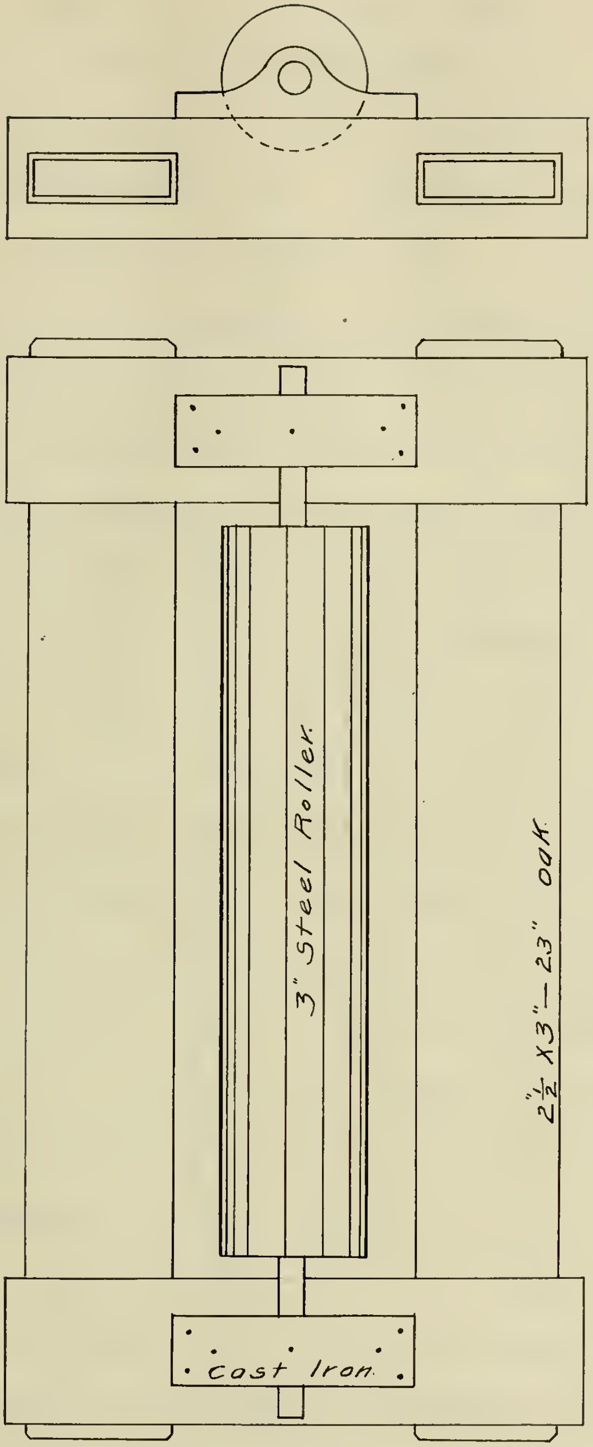

FIG. 6.

DOLLY.

erection of the new structure.

Erection of the New Bridge

The floor beams of the new bridge were moved with the dolly from the points where they had been placed by the haulers (see Fig. 3, page 4) to their proper positions. They were spaced by channel stringers, and the ends were lined by eye. A row of stringers was bolted at each side of the roadway. The beams were then blocked up to an elevation slightly higher than they would have in the finished structure. The blocks under a floor beam were rested upon the cap of the pile bent whenever the old floor beam was not very near this cap. This precaution prevented any final deflection of panel points due to the elasticity of the lower gangways as would occur if the blocks a, Fig. 7, page 10, were omitted. The lower lateral rods were now put in place. In each panel the ends of one lateral rod were placed higher than the ends of the other. The rod with the higher ends was placed with its center below the other rod, so that after the rods were tightened they were held tightly together and vibration and noise prohibited. A row of eye-beam stringers was now bolted to the floor beams at the center of the roadway. Next a number of old flooring boards were placed across the three rows of stringers at a distance from each other equal to half the length of an old floor plank, and a double row of old floor boards was laid at either side of the roadway, and a single row near the middle of the roadway. At the ends of the bridge,approaches of old stringers were also laid, the ends and centers resting upon blocks, in order that material could be easily hauled onto the bridge with dollies.

Three men then moved the intermediate posts onto the falsework, laying each lengthwise of the bridge with its top about six feet

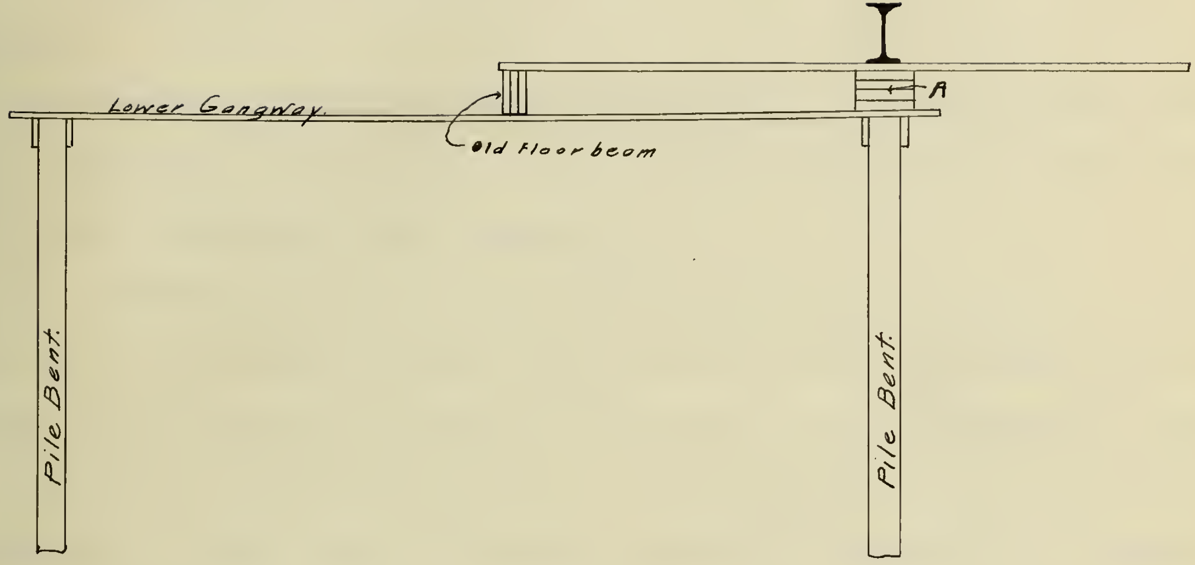

FIG. 7.

SHOWING METHOD OF TRANSFERING LOAD TO PILE BENTS DIRECTLY.

from its corresponding panel point, the foot of the post being toward the center. The remainder of the gang meanwhile constructed a derrick similar to the one previously described, but large enough to raise the top chords to place. It was fitted with a rough ladder. The use of two derricks on this bridge was probably unnecessary. The old bridge could have been torn down perhaps easier by lifting the top chord with pinch-bars or a stringer used as a pry than it was dismembered with the derrick. Although no material was wasted in the construction of the smaller derrick, several hours' time was consumed.

One man was now set at work painting, and was kept at that work until the bridge was finished, the painting being done for the most part before the parts were assembled.

The derrick was set up with the block hanging directly over the south end of the second floor beam from the west. The block was then lowered and attached by a chain to the top of the intermediate post to be placed at that panel point. The post was raised to place by pulling on the fall line. When the post was at exactly the correct height the fall line was fastened securely to the derrick. Two men, one on each side of the floor beam, now bolted the post to the floor beam, while a third climbed on the derrick to the top of the post to steady it and also to incline it as directed by the men making the connection. There was no field riveting to be done, the floor beams being bolted to the posts. All inaccuracies of punching, which could not be remedied by weaving the top of the post about, were corrected with a drift pin, which is a round steel pin 6 inches long and about 3/8 inch in diameter at one end and 1 inch in diameter at the other. After the bolts were inserted and the nuts tightened with

a wrench, the head of each bolt was struck with a sledge by one man while another with a wrench tightened the nut as much as possible. When this post had been secured, the derrick was moved to the others in turn, and they were raised in the same manner. Figure 8 is a photograph showing the men erecting an intermediate post.

The diagonals, counters, and lower chord members were now carried upon the falsework. These members had been piled by the haulers at the east end of the bridge, no attempt being made to separate them or to place them with the proper end towards the bridge.

Six men, divided into three squads of two each, carried the members onto the bridge. As each bar was picked up the foreman told the men where it belonged and whether it should be turned end for end or not. To do this the foreman must know the size of each piece in the bridge and be able to recognize it at once, and he must also know the size of each pin. The foreman has very little time to study the plans in the field, and this work he must do in the evening that he may not delay the work.

The lower chord was now connected, the men working in two squads of three each, on each truss. Beginning at one end, the lower chord was laid on the falsework as close as possible to its final position. The pin for the joint L_1, for example, was first brought out and both nuts removed. The members were now placed upon this pin with the proper pin fillers, part of the members being placed upon the pin from each end. The nuts were then screwed on and tightened. The joint next in order was then connected. Not only the lower chord, but also all other members, posts, diagonals, and counters, were placed on the pins, care being taken that the packing, that is, the order and spacing of the pieces on the pins, was correct. If any floor beam was not in the proper place to receive the members, it

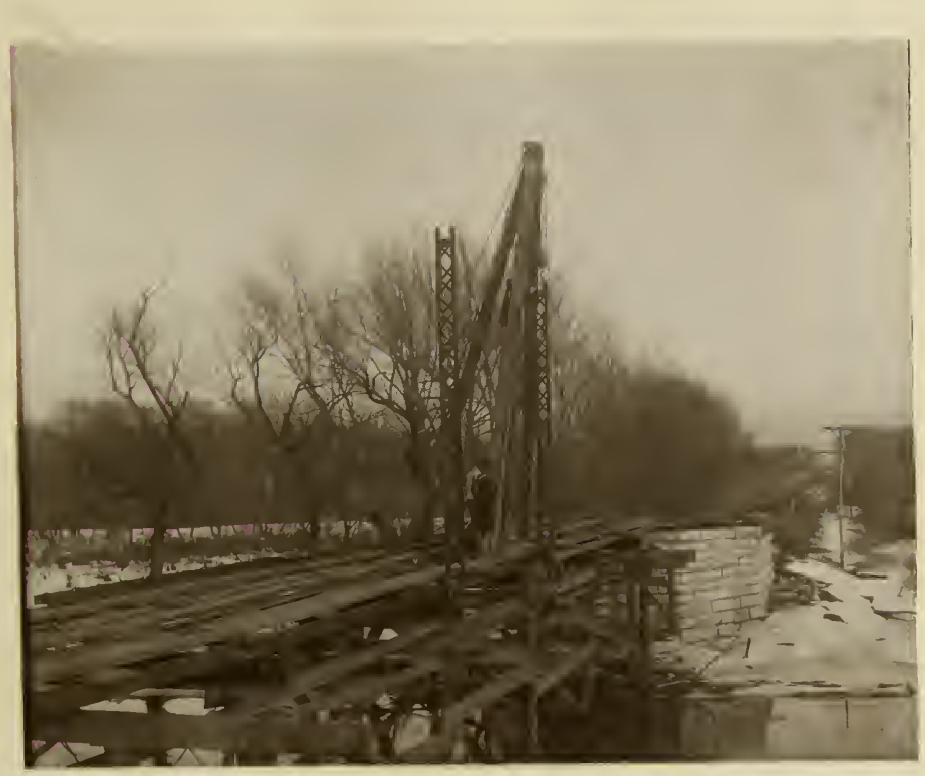

FIG. 8.

ERECTION OF INTERMEDIATE POST.

was moved with a pinch bar or a sledge, or if a chord member was too long by a small amount, the latter was bent out at the center. All tension members were connected without the use of pilot nuts on the pins. Each pin was carried from the box on the bank when it was needed, and great care was taken that no pieces fell into the river, as no duplicate parts were furnished. The wrenches for the pins had a steel handle about 18 inches long. This handle was about 3/8 inch in diameter at the end and 3/4 inch in diameter near the wrench. This handle was used as a pilot bar and was of great assistance in placing the members on the pin. The bar was run through all members in order before the pin was started and they were thus held closely to place.

The top chord was next run out on the falsework. To do this the men laid a runway of plank from the falsework to about the middle of a section of the top chord. The dolly was then placed on the runway, roller down. All hands now lifted one end of the chord member and swung it out over the runway. When the middle part was over the dolly, the member was rested on the dolly and then swung parallel to the runway. The dolly was then placed with the roller perpendicular to the chord member and a little further from the bridge than the center of gravity of the member. A rope about 20 feet longer than the chord member was then fastened at its center to the dolly and two men pulled the member upon the bridge, while a third at the rear end kept the member clear of the runway by his weight and steered. Whenever two men were not able to pull the section onto the falsework others assisted them, but as room was limited on the falsework the work was done by as small a number as possible. Each member of the upper chord and the end posts were moved in this

manner and laid on the falsework in their proper positions and as near to the intermediate posts as convenient.

In erecting the top chord the following order was carried out: One truss was completed first, then the other truss; afterwards the top struts, lateral rods, and portals were connected. Each truss was erected by first lifting the member $U_1U_2U_3$ by the derrick attached at U_2 (see Fig. 1, page 2) and making the member fast to the posts L_2, L_3 by the required number of bolts, each joint being finished as far as compression members were concerned before it was left. The derrick was then moved to a point about one-fourth of the distance from L_1 to L_0. The block was fastened to the end post and it was hoisted to place and secured at its junction with the top chord by the required number of bolts.

After the top chords had been bolted to place the diagonal members meeting at a joint were raised from the falsework, by ropes lowered from the top chord, and were sprung so that the ends entered the space between the channels of the top chord. The pin for this joint was fitted with a pilot and a driving nut while on the bank and then carried to the joint. One man clung to the intermediate post and held the pin in position, while a second stood on the top chord and drove the pin to place with a sledge. The floor beams had been placed so high that none of the web members were short enough to bind on the pin, but most of them did thus bind because they were too long. To remedy this three methods were employed, viz.: the web members were sprung out at the center, or they were shortened by changing the turn-buckle, or the floor beam was moved a little by a pinch bar. Of course the second method can be employed only for the middle panels (those having counters), and the third

only near the end of the bridge. Either of these two methods will change the position of the floor beams rather than that of the top chord; but if the truss has been already located in a plane, the method of springing the bar gives sufficient change of length. The pilot nuts were unscrewed, after the pin had entered the hole, by a pilot wrench, which is merely a round bar of steel about 1/4 inch in diameter, which enters a hole in the pilot nut transverse to the axis of the pin. The bar being 18 inches long, the nut was easily removed.

When all the joints in the trusses had been connected a top strut, say U_3L_3, Fig. 1, page 2, was raised to place by two men, one on each truss, pulling on a rope attached to the end of the strut. The ends of the struts were designed to fit over the inner Lomas nut of the pin in the top chord. The trusses were sprung apart enough to admit of the pins entering the hole in the plate on the end of the strut, and then the Lomas nut on the inner side of each truss was screwed onto the pin until the end of the pin was flush with the face of the nut. The outside nuts were then screwed to a tight fit with a large wrench.

The portal was next placed in position. It was raised by men standing on the top chord and pulling on ropes. The portal was bolted securely to place, each bolt being struck with the sledge several times while the nut was being tightened. The top lateral rods were then lifted to place and fastened, the same precautions against vibration and noise being taken as were taken in the case of the lower lateral system. The bridge was then ready to swing off the falsework.

The act of removing the weight of a bridge from the falsework

and making the structure self-supporting is called swinging the bridge. First all lateral rods are given the desired amount of initial tension, and the counters are shortened by screwing the turnbuckle. If the bridge is not raised off the falsework by tightening the counter, the blocks under the floor beams may be knocked out with a sledge.

While the remainder of the workmen were swinging the bridge, two men punched bolt holes in the stringers. These members were sent direct to the bridge site from the rolling mill, and hence the holes were punched on the site. A screw-punch similar to that shown in Fig. 9 was used. A bar of iron four feet long was used to turn the screw, and the holes were easily punched. The joists were then painted before being put in place. The gangways on the west panel of the bridge were now removed and the stringers for this panel were carried by two men to their proper place and were then bolted to the floor beams. When all the stringers in the west panel were in place, the second panel from the west was fitted in the same manner, and so on to the east end of the bridge. The nailing pieces were then carried out and bolted to the joist. The floor was then laid from the east toward the west, the lumber having been piled at the east end of the bridge.

After the floor was finished the felloe guards were bolted down and the railing was bolted to the posts. The parts which were not painted on the ground were now painted.

The only remaining step was the removal of the falsework. The gangways and blocks which supported the floor beams and also the old floor beams were lowered from one bent to the next by men at each bent until they reached the ground. The caps were then removed from

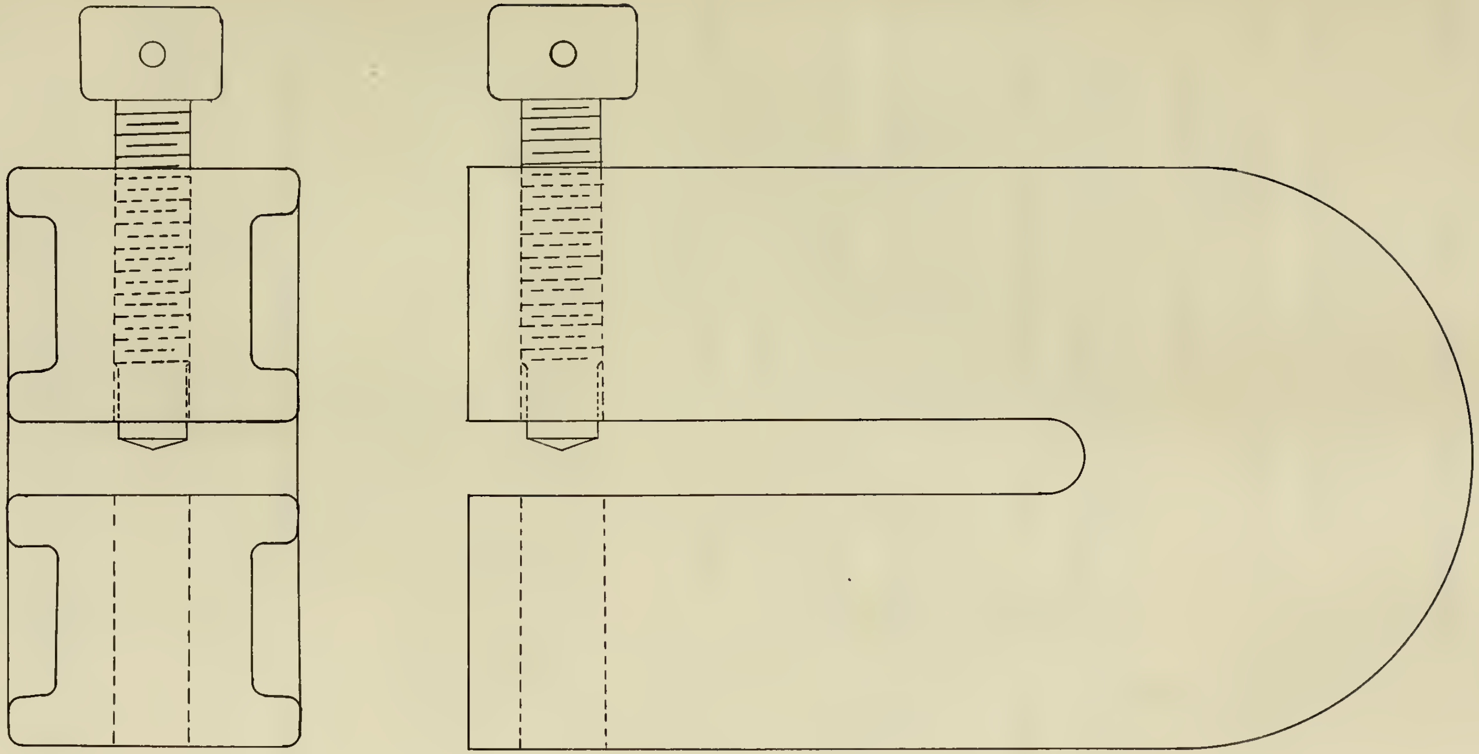

Fig. 9.

SCREW PUNCH.

the bents and passed to the bank. Heavy pieces were allowed to fall into the water, a rope having first been attached by which they were pulled to shore. The braces were then removed and the piles were easily lifted by a block and tackle fastened to the bridge. The cast iron piles of the old bridge were broken off near the surface of the ground by knocking the flanges off with a sledge and then breaking the slender center portion with a blow from a sledge or a pull with a block and tackle.

Discussion of General Methods of Erection

POSITION OF SPLICE IN TOP CHORD.- The splices in the top chord were placed about one foot from a post. The portion of the chord having a post near its end must be erected first, and the portion to be connected to this may be put in place afterward. That is, if in a bridge with an odd number of panels the splices are placed at A and B, Fig. 10, the portion A B of the chord must be erected first and then the portions toward the ends. If, however, the joints are placed as shown in Fig. 11 at A and B, then the end portions must be first erected.

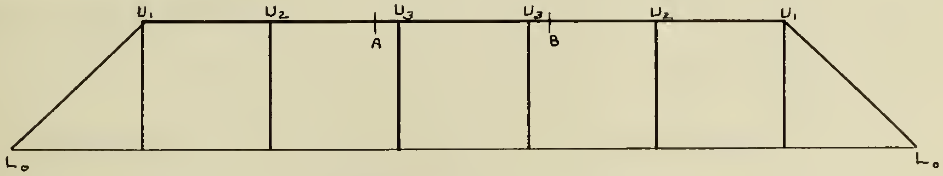

Fig. 10

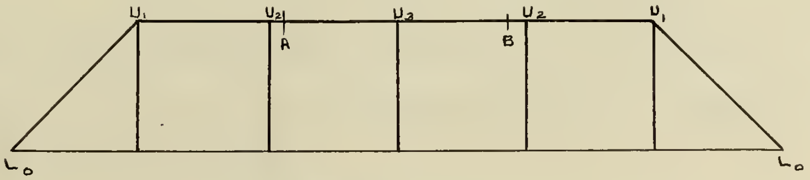

Fig. 11

It is thus seen that the design of the bridge may in a measure control the method of erection. In most cases the end post will be erected after the segment U_1U_2 is in place.

TRAVELER VS. DERRICK.- Bridge erection by means of a derrick has been fully explained in the preceding pages. The method of erection with a traveler is shown by the photograph, Fig. 12, page 21. The use of the derrick is usually recommended on single spans up to 150 feet; but on longer spans and on bridges of two or more spans of the same size, it is better to use a traveler, as time and stability will thereby be gained.

FIELD BOLTS VS. FIELD RIVETS.- Field bolts are not permitted in highway bridges by most standard specifications, field rivets being required instead, unless turned bolts are used in reamed holes. The use of commercial bolts in punched holes is disadvantageous because the bolts in a joint do not fit perfectly, and hence do not all take the same amount of strain. If the holes were reamed, instead of punched, as they usually are in railroad-bridge work, and if the bolts were turned to a driving fit, this objection would be practically void. The chief advantage of field bolts over field rivets in highway-bridge work is the ease with which the former are used. Five men skillful at riveting are required for a riveting gang, and as the ordinary highway bridge gang consists of not more than four skillful men and often only one, the work will be greatly hampered by unskillful or ignorant men. Another disadvantage of field rivets in small bridges is the large expense of shipping the riveting appliances required in driving. The number and weight of tools required to construct a riveted bridge is almost double that required for a bolted bridge.

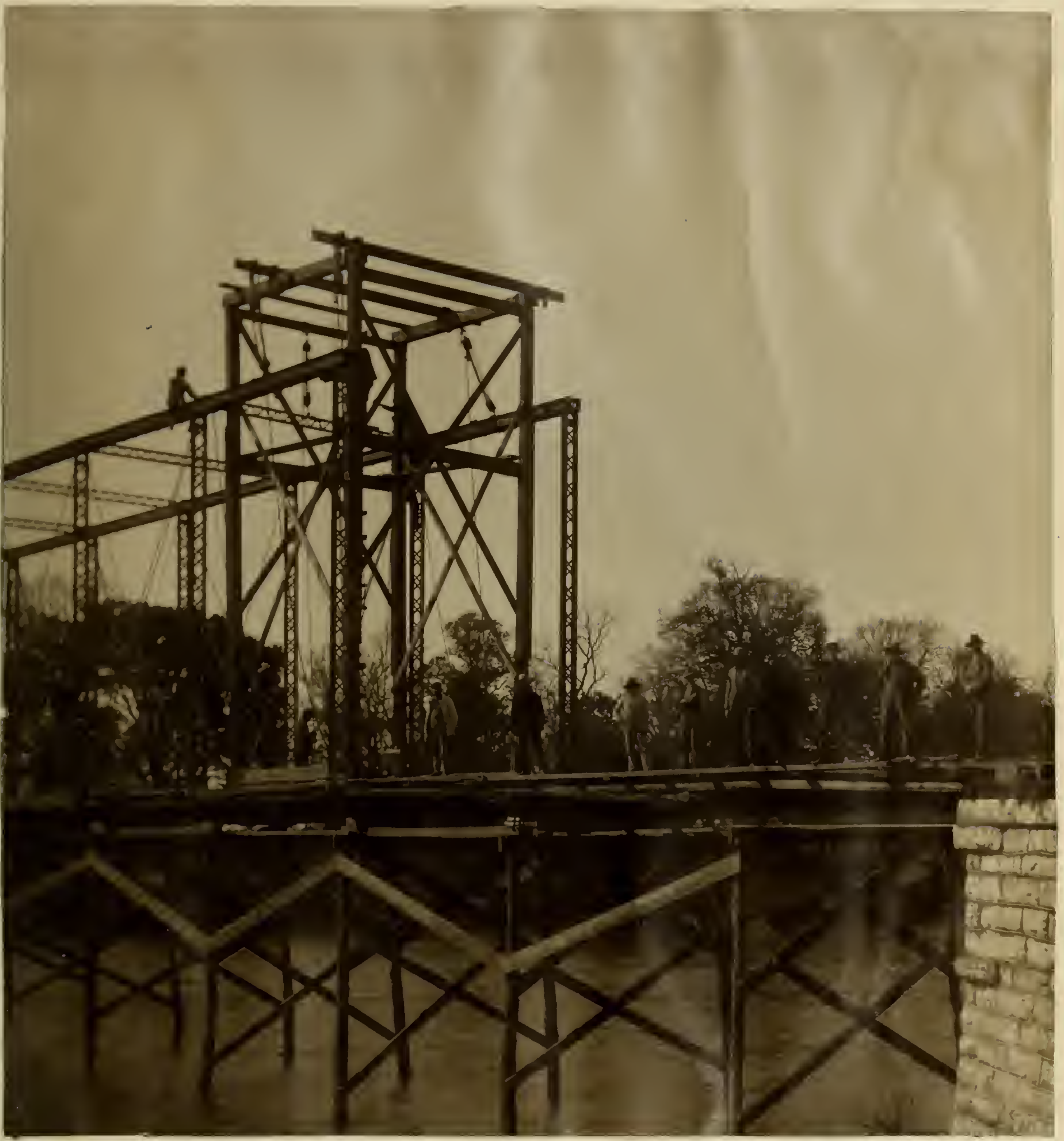

FIG. 12.

ERECTION WITH TRAVELER.

Bolts are probably superior to rivets for small bridges on account of their low cost and ease of erection, but the allowable stresses in bolts should be very low, as is permissible since the cost is quite small. A good field bolt may be stronger than a poorly driven rivet.

Cost of Erection

The cost of erection of the bridge at St. Joseph was as follows:-

1 Foreman - - - - - - - -	6 da.	at $4.00 =	$24.00
2 Skilled laborers- - -	6 "	" 2.50 =	30.00
4 Unskilled " - - -	6 "	" 1.80 =	43.20
Hauling - 22 tons -	2 mi.	" .20 =	8.80
Total, exclusive of transportation of men and of time lost in traveling			$106.00

A good safe estimate on erection, including hauling, for bridges of the size under discussion is:

For work on tubular piers - $1.50 per linear foot.
" " " masonry " - 1.00 " " "

These estimates do not include painting. Nine gallons of paint were required on the St. Joseph bridge, the cost of applying the paint being about $1.00 per gallon. Many erectors allow one gallon of paint for each 10 ft. of length of span.